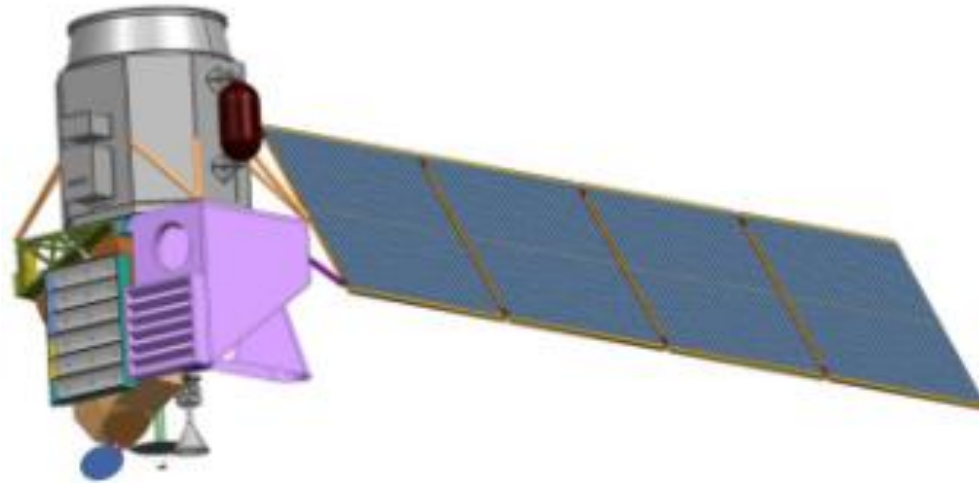




# **HyspIRI: Hyperspectral Infrared Imager**



**Earth Observing Satellites and Conservation NGO User Group  
Workshop**

**World Resources Institute in Washington, DC  
November 10, 2010**

**Woody Turner  
Earth Science Division  
NASA Headquarters**

# HyspIRI Measurements

## Imaging Spectrometer (VSWIR)

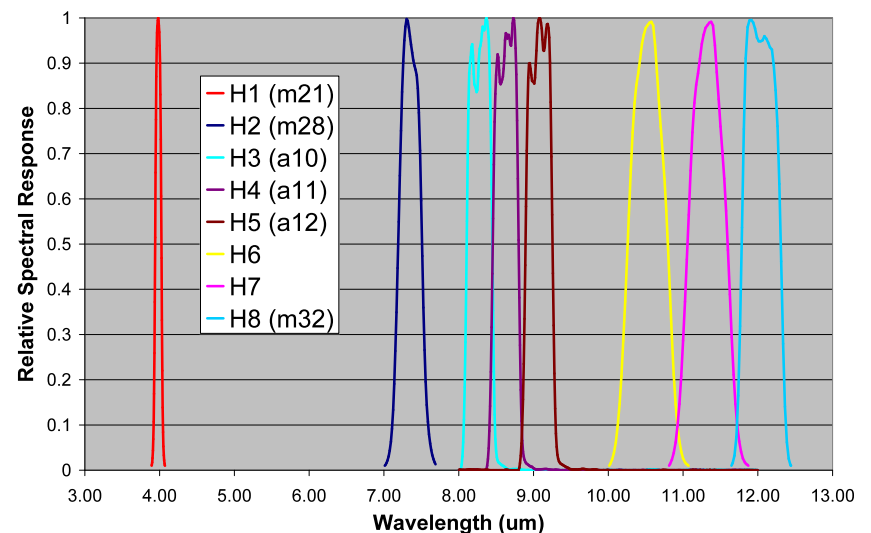
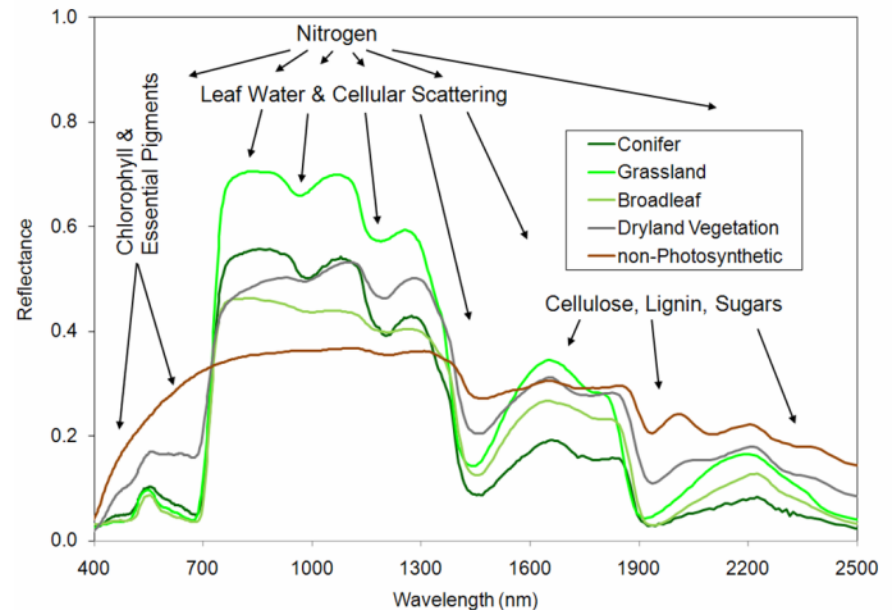
- 380 to 2500 nm in 10nm bands
- Accurate 60 m spatial sampling
- 19-days revisit
- Global land and shallow water ( $\leq 50\text{m}$ )

## Thermal Infrared (TIR):

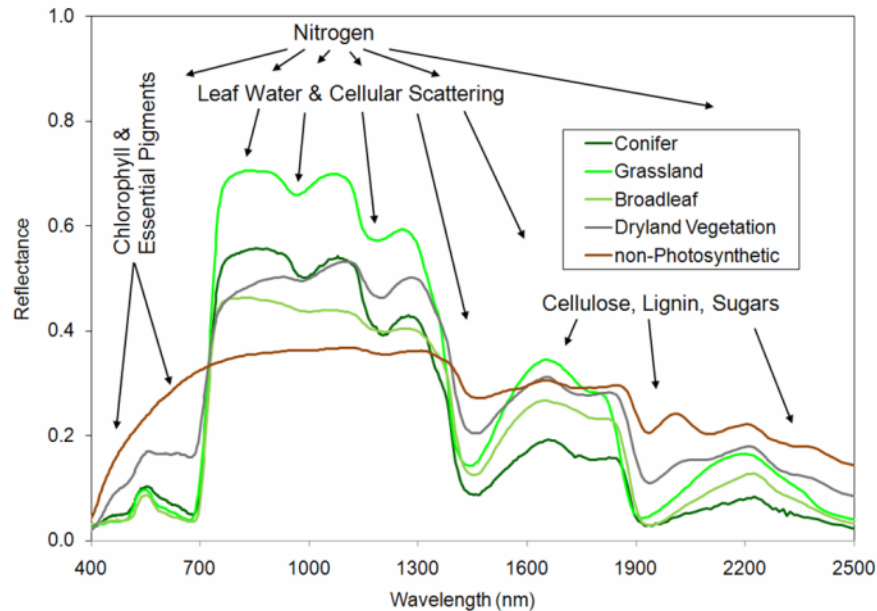
- 8 bands between 3-12  $\mu\text{m}$
- Accurate 60 m spatial sampling
- 5-days revisit
- Global land and shallow water ( $\leq 50\text{m}$ )
- Day and night coverage

Ice sheets and deep ocean averaged at 1 km

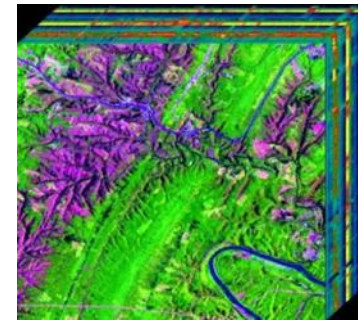
HyspIRI Mission Concept is high heritage, low risk, mass, power and cost.



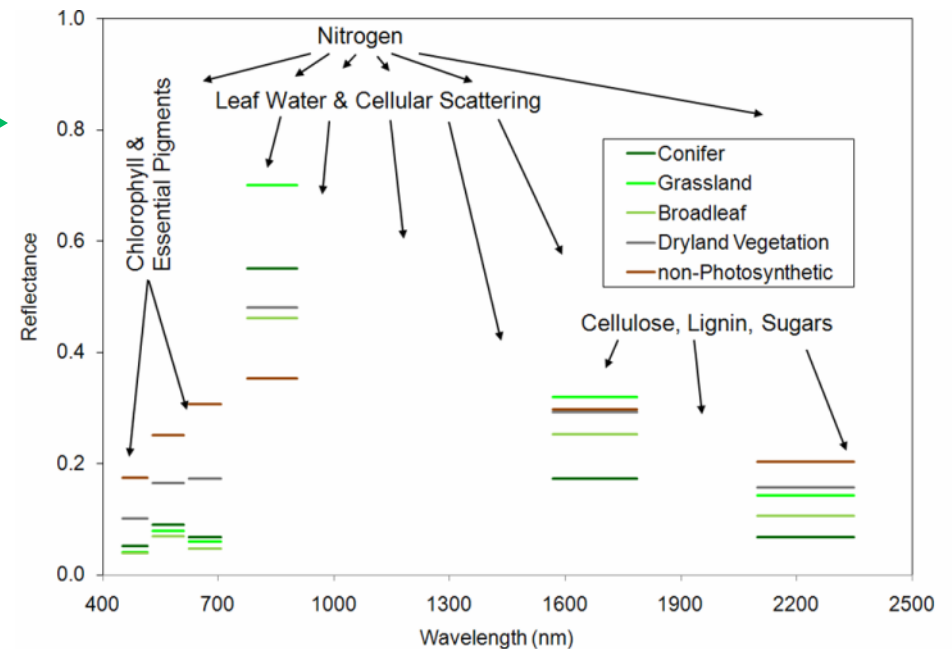
# The Power of the Full Spectrum



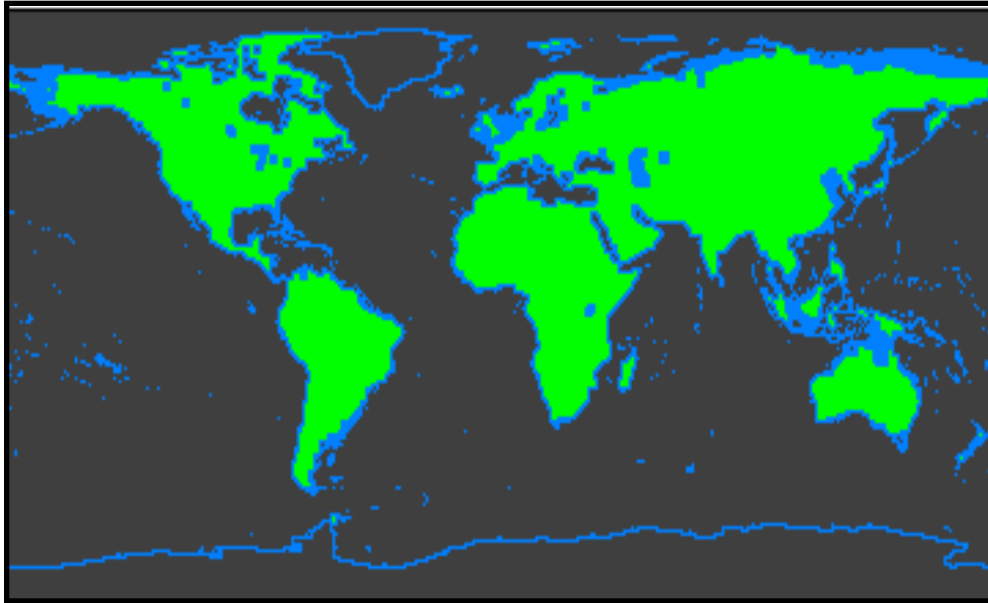
← Imaging Spectroscopy is required to measure critical variables of the terrestrial biosphere.



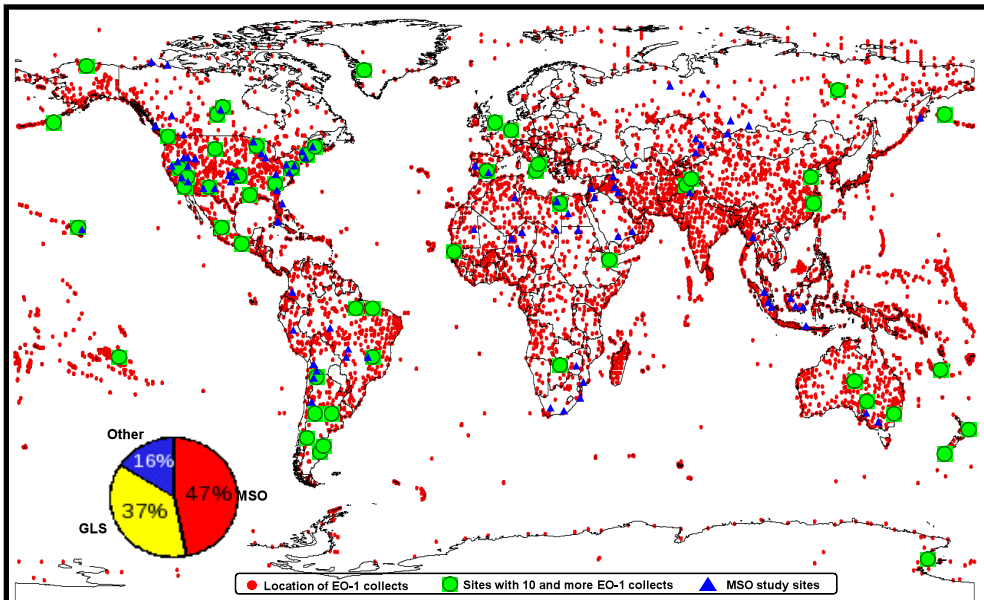
Multi-spectral imaging is insufficient →



# Global Coverage



- HyspIRI VSWIR provides complete terrestrial coverage every 19 days.
- HyspIRI TIR provides complete terrestrial coverage every 5 days.
- More coverage at higher latitudes
- HyspIRI (VSWIR and TIR) will have orders of magnitude more scientific coverage and quality than any other planned mission.



- EO-1 Hyperion acquisitions in 10 years, from a technology demonstration sampling mission.
- It would take Hyperion ~100 years to acquire what HyspIRI measures in 1 year.

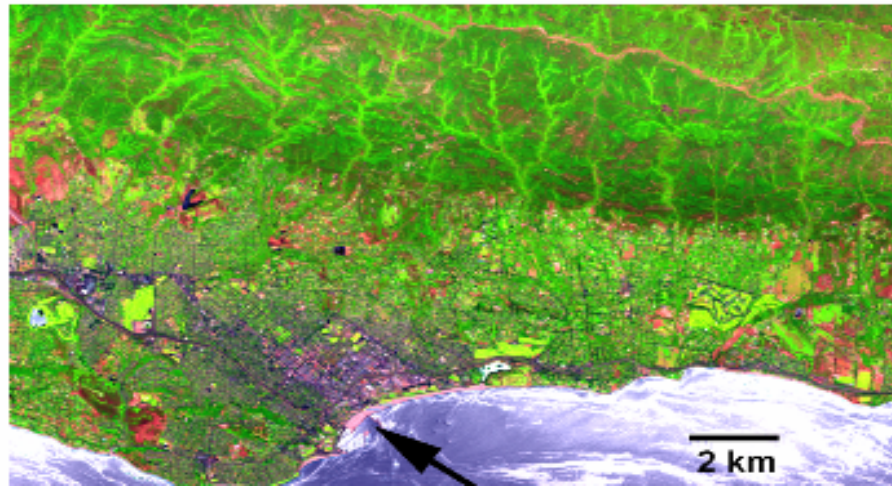
# Key Climate Science Themes

- **Ecosystem Measurements for Climate Feedbacks:** Global vegetation species/functional group-type and physiological condition, including agricultural lands.
- **Land Albedo, Black Carbon/Dust Effects on Snow and Ice:** Spectroscopically derived terrestrial land cover composition /albedo including snow/ice/dust-climate interaction.
- **Fire for Carbon Release from Biomass Burning:** High spatial resolution fire: fuel, occurrence, intensity and recovery globally.
- **Evapotranspiration and Water Use and Availability:** Fine spatial and temporal scale measures of surface temperature and energy balance, including urban heat Islands.
- **Critical Volcanic Eruption Parameters:** Precursor temperatures, eruptive lava temperatures and ash and gas cloud properties

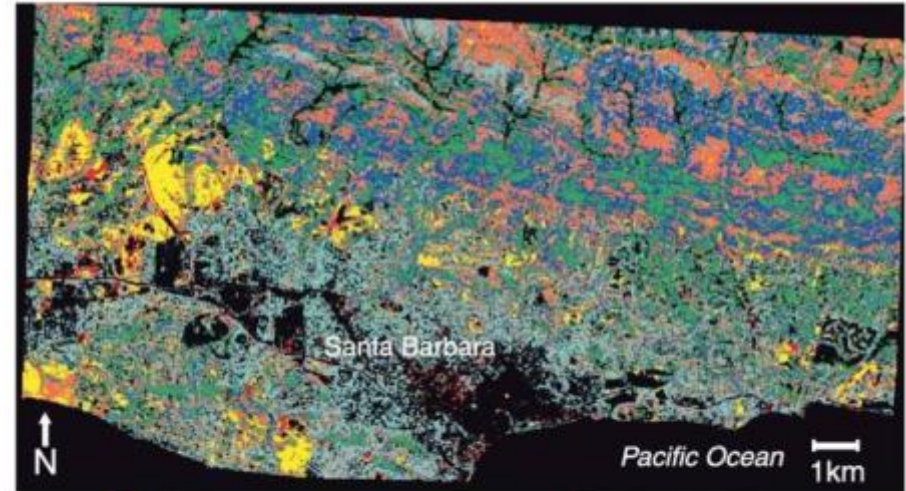
# Ecosystem Measurements for Climate Feedbacks

## Vegetation Species/Functional-type & Fractional Cover

Santa Barbara, CA Coast Range

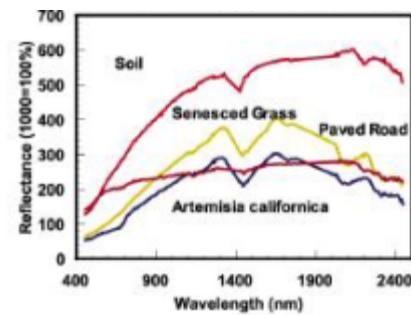
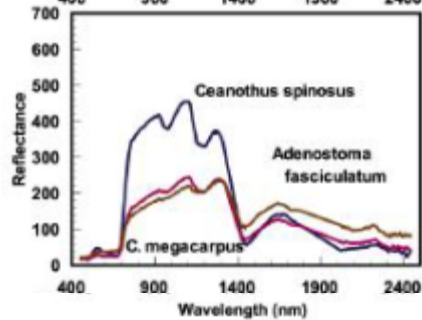
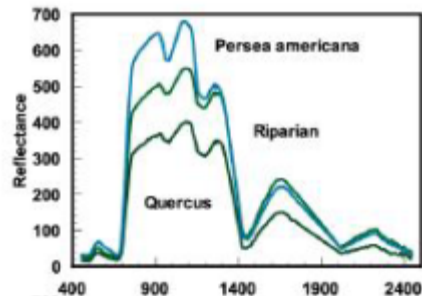
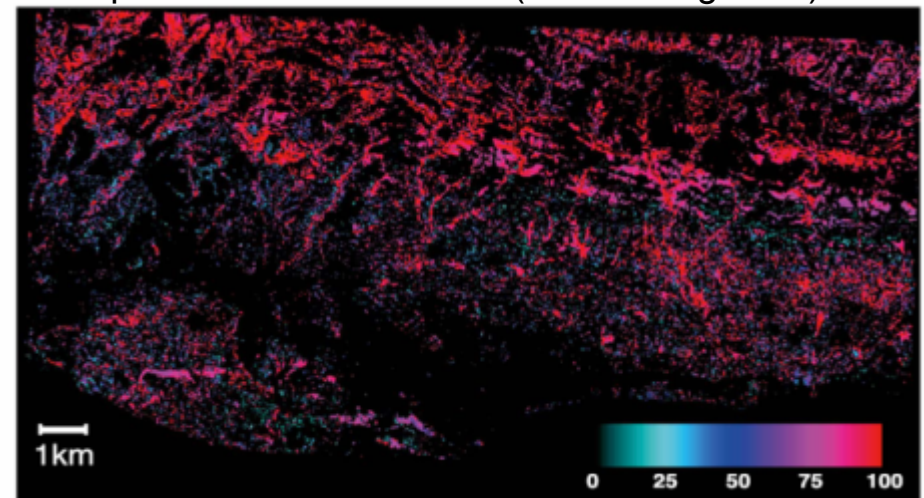


Species Type 90% accurate

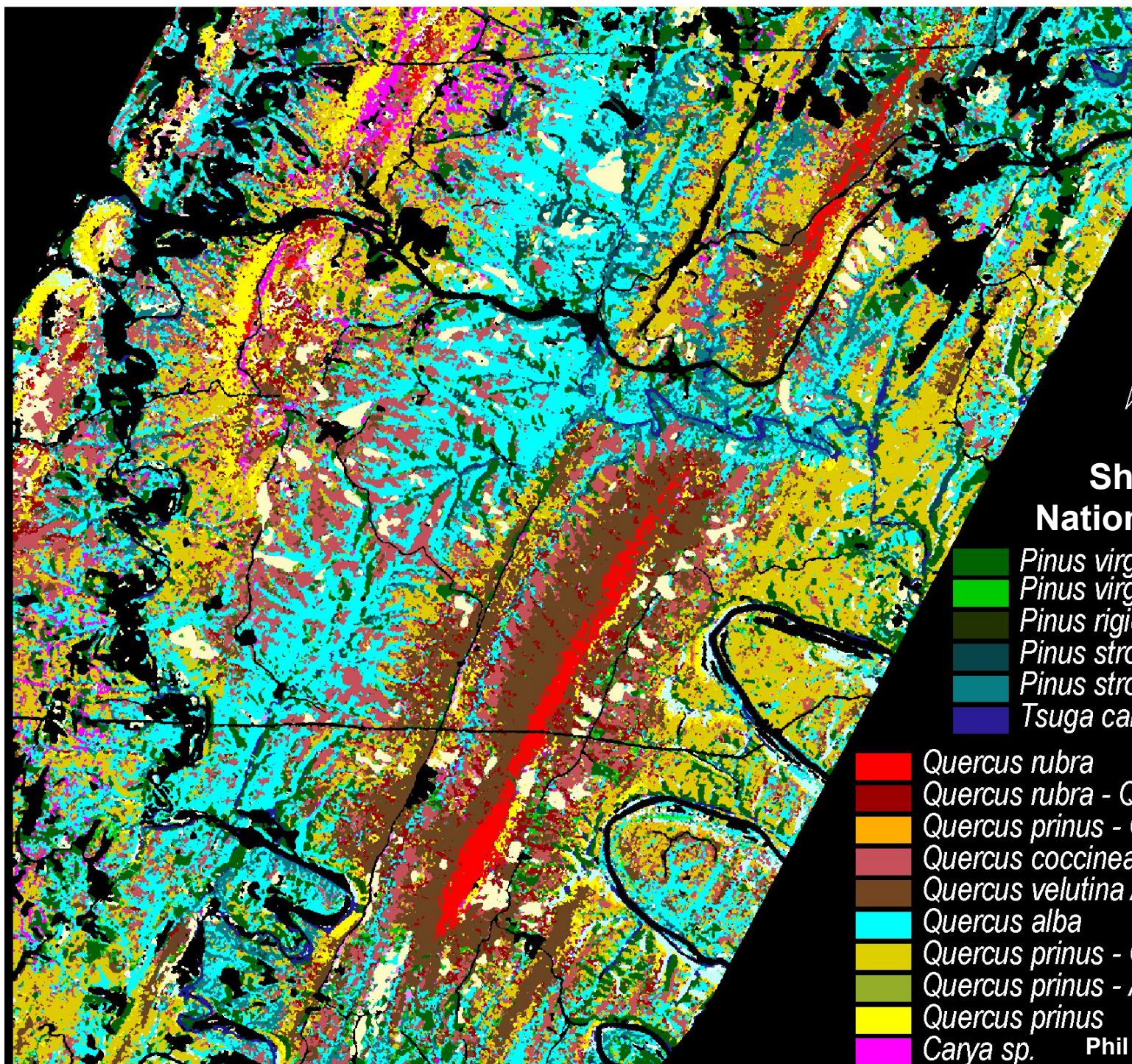


■ *Adenostoma fasciculatum*
■ *Quercus agrifolia*  
■ *Ceanothus megacarpus*
■ Grass  
■ *Arctostaphylos* spp.
 ■ Soil


Species Fractional Cover (*Quercus agrifolia*)



Dar Roberts, et al. UCSB

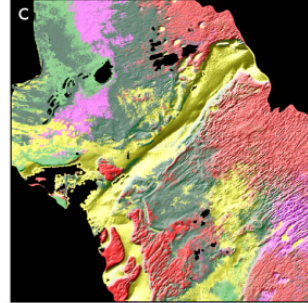
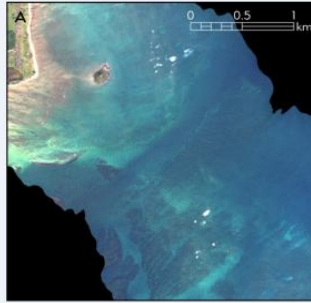
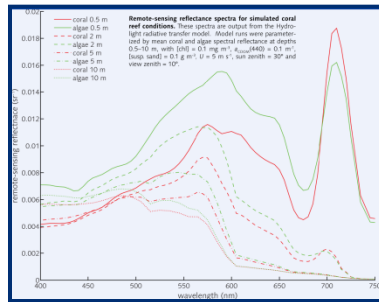


**FT Map  
Shenandoah  
National Park, USA**

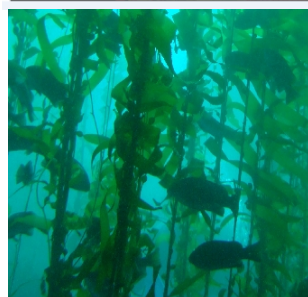
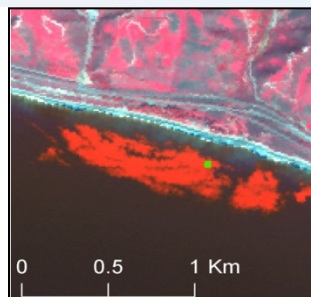
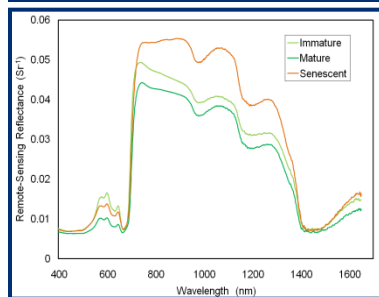
-  *Pinus virginiana*
-  *Pinus virginiana* / deciduous mix
-  *Pinus rigida*
-  *Pinus strobus*
-  *Pinus strobus* / *Quercus* mix
-  *Tsuga canadensis*
-  *Quercus rubra*
-  *Quercus rubra* - *Quercus* spp. - *Carya*
-  *Quercus prinus* - *Quercus coccinea*
-  *Quercus coccinea* / mix
-  *Quercus velutina* / mix
-  *Quercus alba*
-  *Quercus prinus* - *Quercus* spp. / mix
-  *Quercus prinus* - *Acer rubrum* / mix
-  *Quercus prinus*
-  *Carya* sp.

Phil Townsend, U. of Wisc.

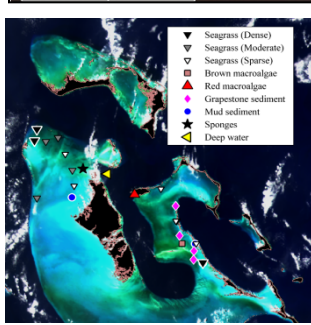
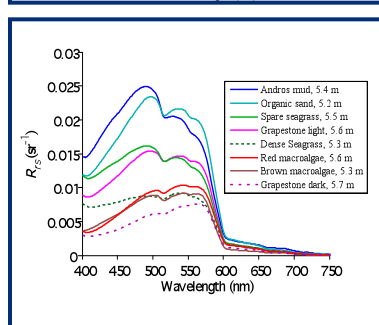
# HyspIRI: Coral, Benthic, and Aquatic Vegetation



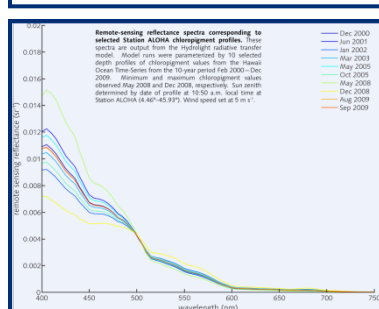
Variation in shallow water HyspIRI-type spectral signatures in coral environments.



Variation in HyspIRI-type spectral signatures of floating aquatic vegetation (e.g. Kelp)



Variation in shallow water HyspIRI-type spectral signatures in seagrass beds and benthic habitat materials

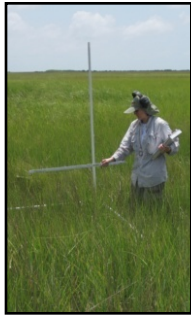


Variation in ocean-color type signals of the deep blue ocean. HyspIRI is not optimized for ocean-color. HyspIRI is designed to support coral, benthic habitat and aquatic vegetation science objectives.

(slide courtesy of JPL/Rob Green)

# NASA imaging spectroscopy used to map vegetation species and physiological condition before and after oil impact (early results)

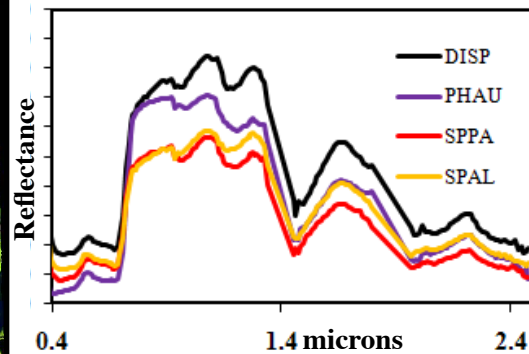
Pre Oil



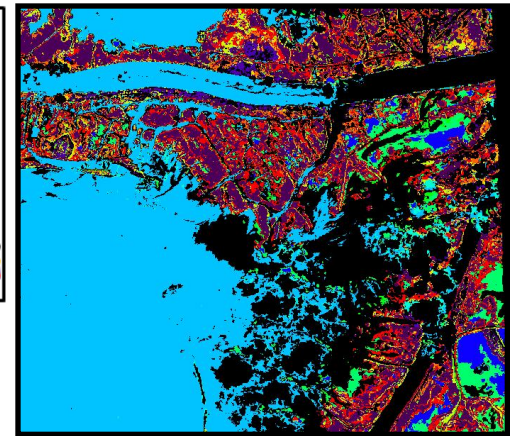
AVIRIS Birdfoot Delta



AVIRIS Vegetation Spectra



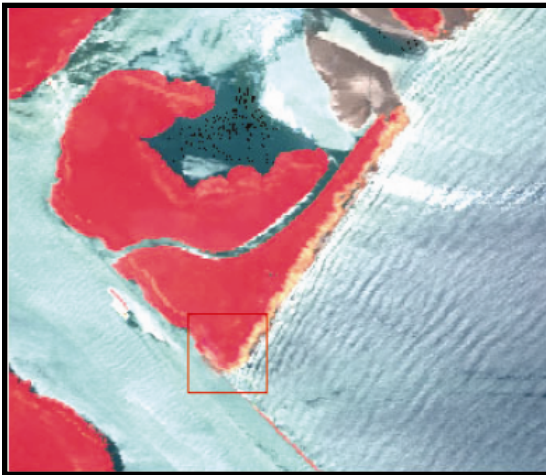
Spectroscopy Based Species Map



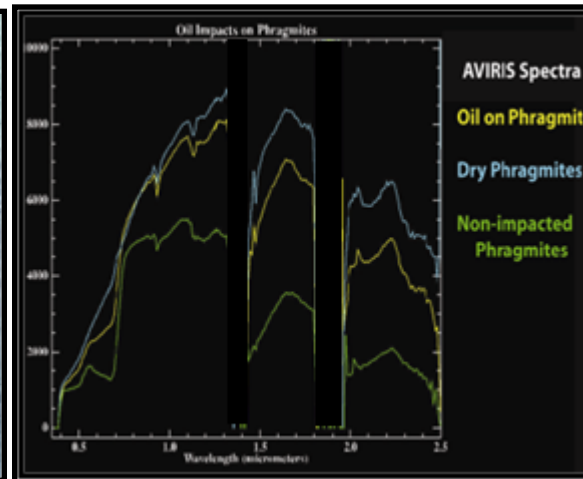
Post Oil



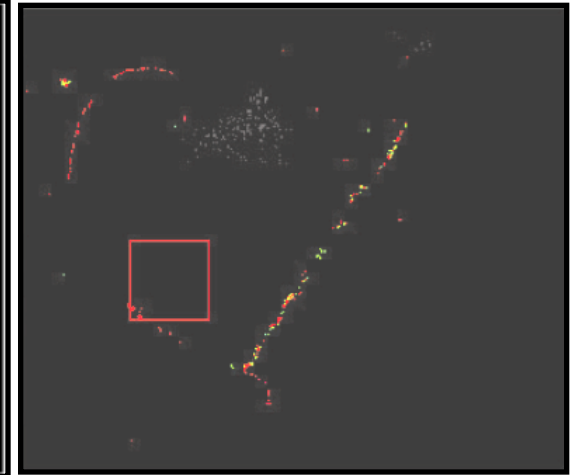
AVIRIS Measurements



AVIRIS Spectra with and without Oil



Oil impacted Vegetation

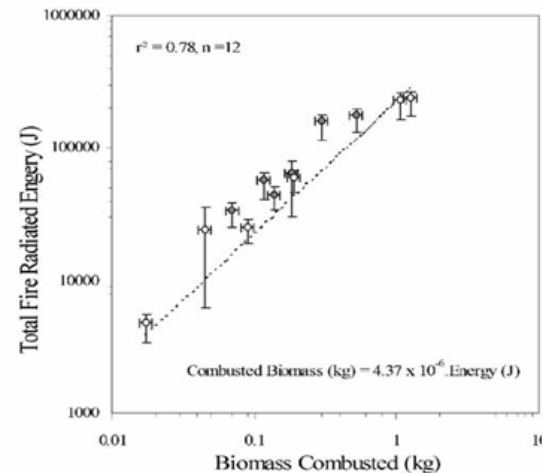
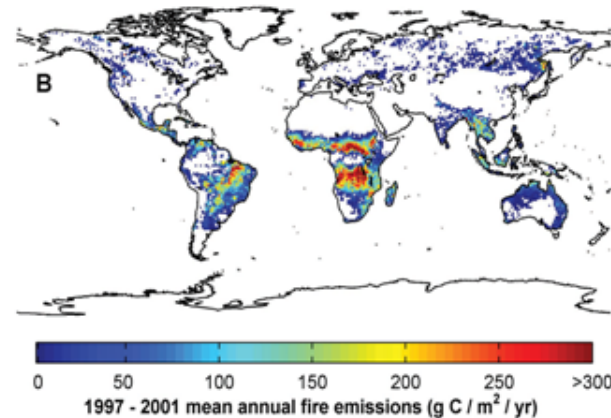


(slide courtesy of JPL/Rob Green)

# Global Fire Emission Estimates

Biomass burning and fossil fuel emissions release  $\sim 10^{15}$  g of carbon (C) to the atmosphere each year. Biomass burning constitutes  $\sim 25\%$  of all global C emissions.

Region	Fire emissions 1997-2009 average ( $10^{15}$ g C yr $^{-1}$ )
Central and northern South America	0.04
Southern South America	0.27
Northern Africa	0.48
Southern Africa	0.27
Southeast Asia	0.04
Boreal (north of 38°N)	0.18
Other	0.73
Global	2.01

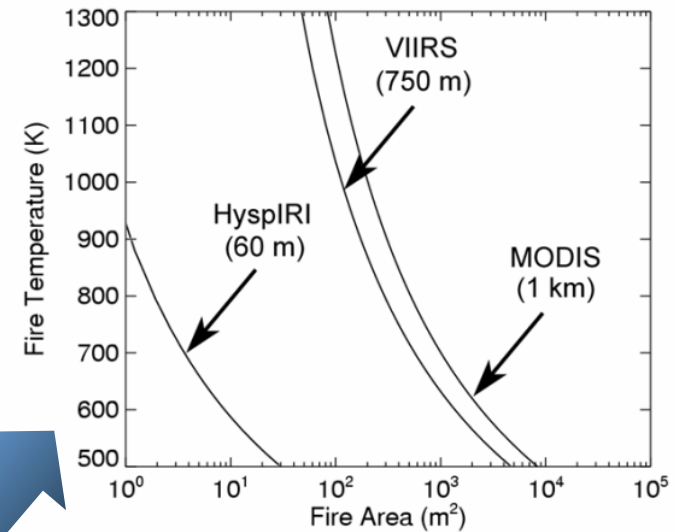
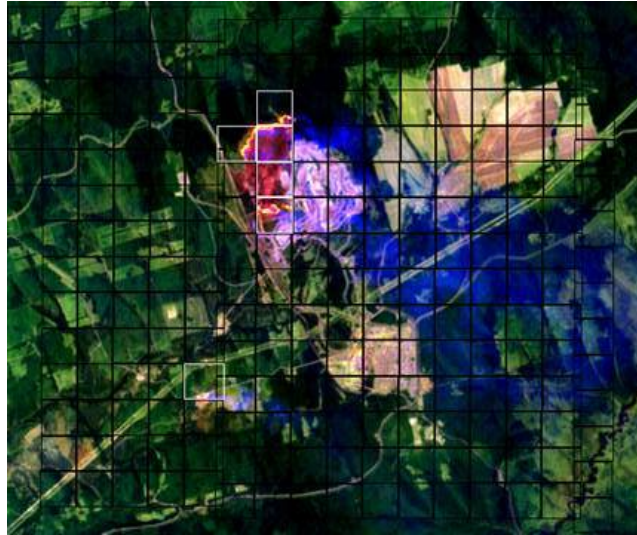


Need 4 um data to measure Fire Radiative Power (FRP) to determine Biomass Combusted

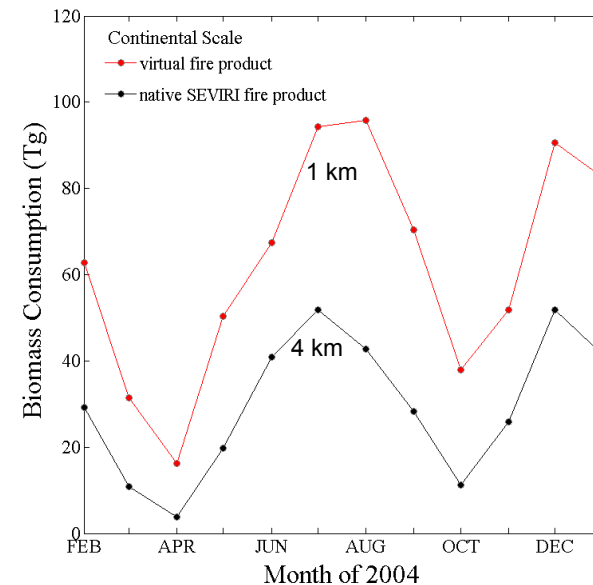
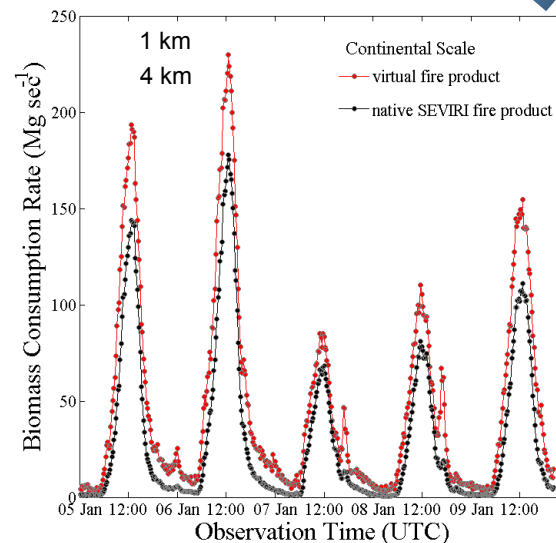
Fires occur worldwide need a GLOBAL Mapping Mission

*Van der Werf et al., 2010; Wooster, 2003*

# HyspIRI-TIR Provides Orders of Magnitude Improvement in Fire Detection



HyspIRI detects agricultural fires which are a major carbon contributor and cannot be reliably detected with 1km sensors



(slide courtesy of JPL/Simon Hook)

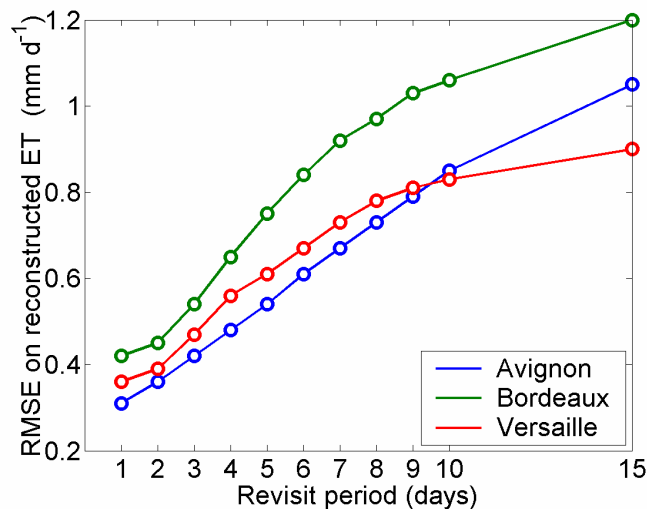
# High Spatial and Temporal Resolution Required to Accurately Measure Evapotranspiration



**(ET)**  
**High spatial resolution:** access to the local scale (field, urban district...)

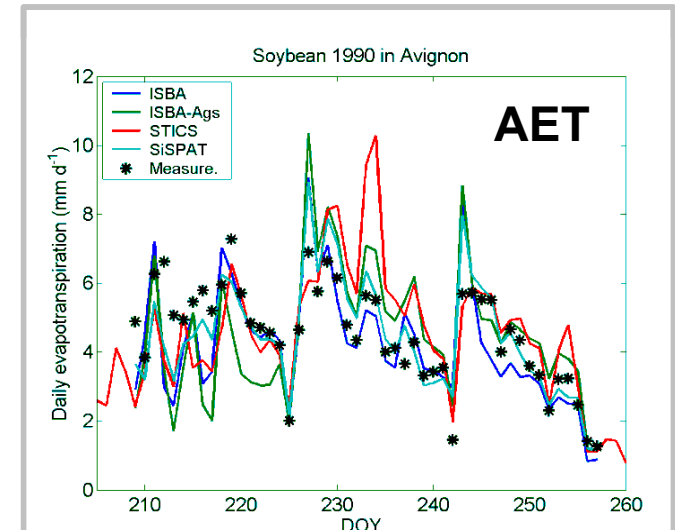
**1 km box**

1 km data does not capture field scale variation

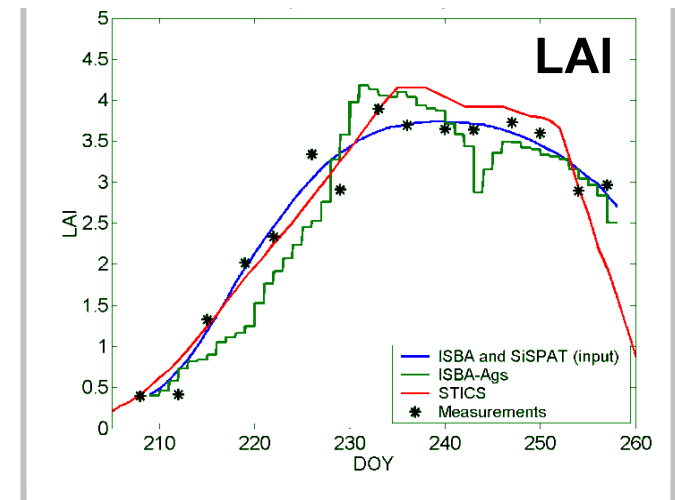


5-day revisit minimizes error on ET Estimation

**High revisit:** rapid response to surface forcing (water status, meteorological conditions...)



ET is very dynamic compared with LAI

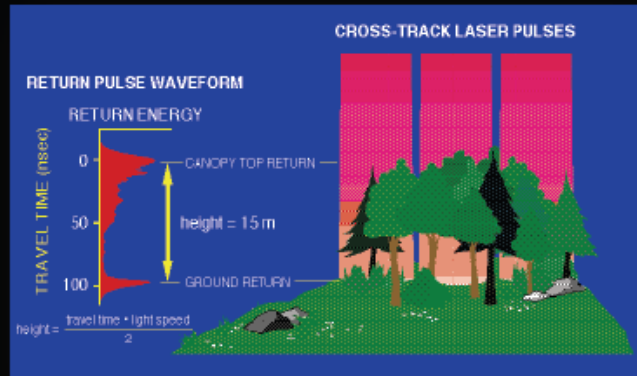


Courtesy Jean-Pierre Lagouarde, INRA, France

# Carnegie Airborne Observatory (CAO)

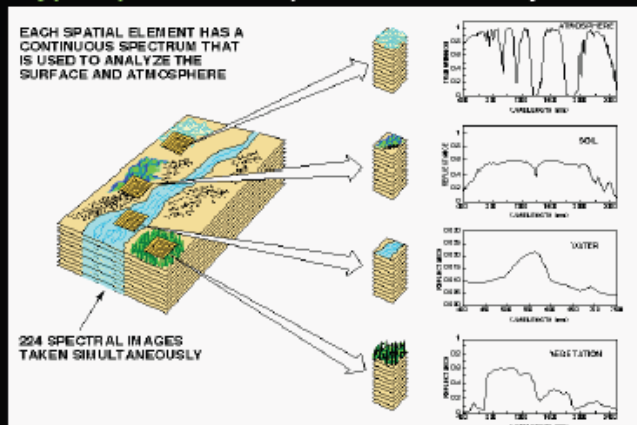
*3-D functional imaging of ecosystems*

**LiDAR** for topography, canopy structure, LAI, etc.

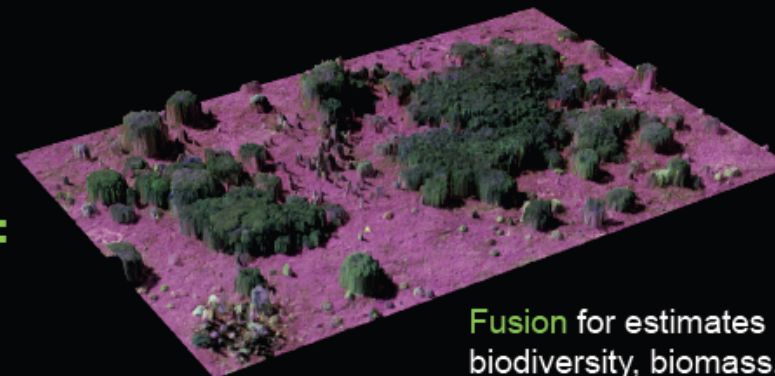


+

**Hyperspectral** for species, chemistry, etc.



=

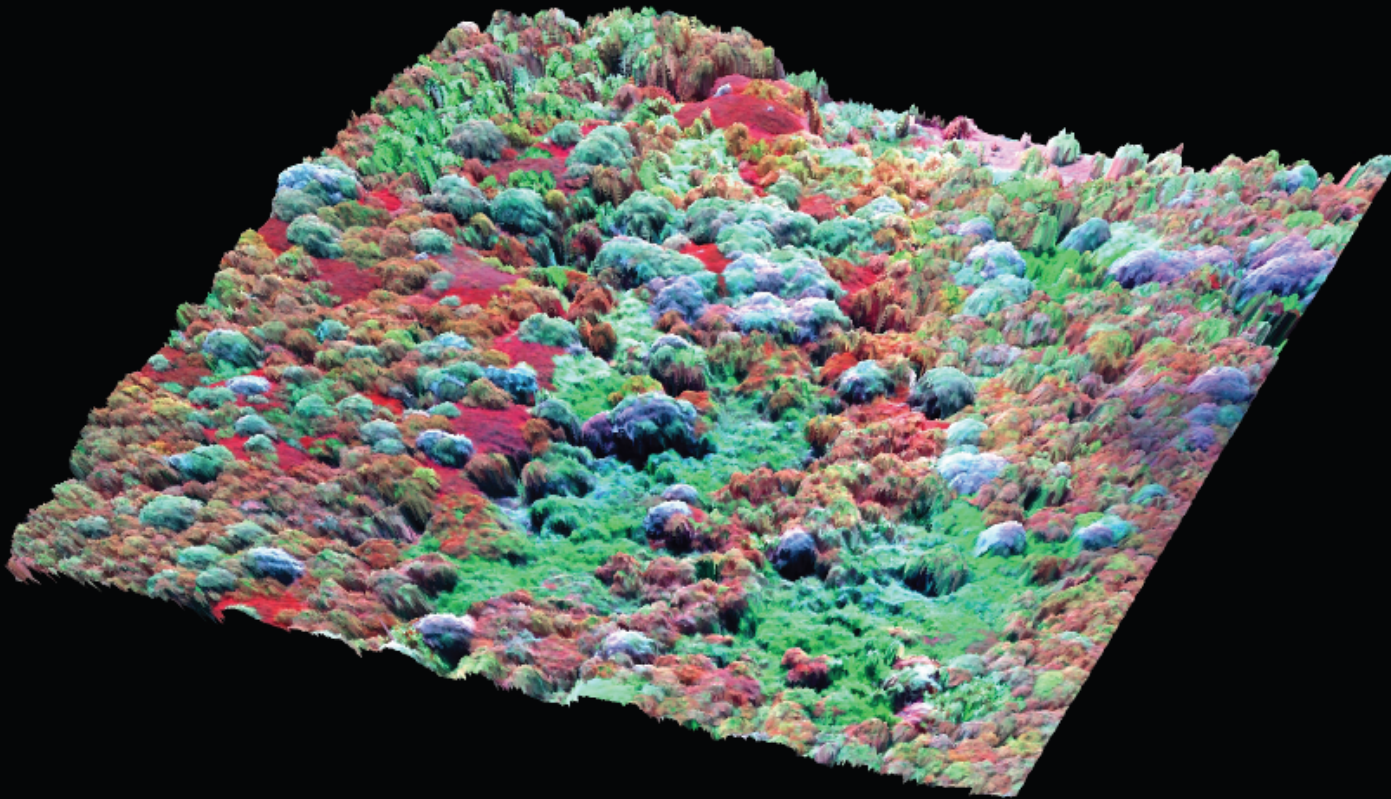


**Fusion** for estimates of biodiversity, biomass, sun/shade fraction, habitat suitability, etc.



Bruce Cook and Greg Asner

# Canopy chemistry and biodiversity in tropical forest canopies



Bruce Cook and Greg Asner

The diagram illustrates the Spacecraft Data System (SDS) architecture. It is divided into two main sections by a dashed line: the **Spacecraft** (top) and **To/From Alaska and Norway Ground Stations** (bottom).

**Spacecraft Section:**

- Sensors:** TIR (Thermal Infrared Radiometer) and VSWIR (Visible Short-Wave Infrared Radiometer) are located on the left.
- Data Flow:**
  - TIR sends data at **130.2 Mbps** to the **Command & Data Handling Solid State Recorder**.
  - VSWIR sends data at **804 Mbps** to the same recorder.
  - Both sensors also feed into the **IPM (Instrument Processing Module)**.
  - The **IPM** contains a **Direct Broadcast Module**.
  - The **Direct Broadcast Module** outputs data at **20 Mbps** to the **Direct Broadcast Antennas**.

**Ground Station Section:**

- Antennas:** Represented by a dish icon, labeled **Direct Broadcast Antennas**.
- Data Flow:**
  - Receives **20 Mbps** from the spacecraft's Direct Broadcast Module.
  - Handles **S-band command** (upward arrow to spacecraft).
  - Handles **S-band housekeeping data** (downward arrow from spacecraft).
  - Handles **X-band 800 Mbps Science data** (downward arrow from spacecraft).

**Legend:** A dashed line separates the **Spacecraft** from the **To/From Alaska and Norway Ground Stations**.

# HyspIRI VSWIR Measurement Characteristics

## Spectral

Sampling	$\leq 10$ nm {uniform over range}
Response	$\leq 10$ nm (full-width-at-half-maximum) {uniform over range}
Accuracy	$<0.5$ nm

## Radiometric

Range & Sampling	0 to 1.5 X max benchmark radiance, 14 bits measured
Accuracy stability	$>95\%$ absolute radiometric, 98% on-orbit reflectance, 99.5%

## Spatial

Range	150 km (13 degrees at 626 km altitude)
Cross-Track Samples	$>2400$

## Uniformity

Spectral Cross-Track	$>95\%$ cross-track uniformity { $<0.5$ nm min-max over swath}
Spectral-IFOV-Variation	$>95\%$ spectral IFOV uniformity { $<5\%$ variation over spectral range}

## Temporal

Orbit Crossing	10:30 am sun synchronous descending
Rapid Response Revisit	3 days (cross-track pointing)

## On-Orbit Calibration

Lunar View	1 per month {radiometric}
Solar Cover Views	$\leq 1$ per week {radiometric}
Surface Cal Experiments	$\sim 3$ per year {spectral & radiometric}

## Data Collection

Compression	$\geq 3.0$ lossless
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# HyspIRI TIR Measurement Characteristics

## Spectral

Accuracy <0.01  $\mu\text{m}$

## Radiometric

Range Bands 2-8 = 200K – 500K; Band 1 = 400 - 1100K

Resolution < 0.05 K, Linear Quantization to 14 bits Bands 2 - 8

Accuracy < 0.5 K 3-sigma at 250K Bands 2-8

Precision (NEdT) < 0.2K @ 300K Bands 2-8

## Spatial

Band-to-Band Co-registration 0.2 pixels (12 m)

Pointing Knowledge 48  $\mu\text{rad}$  (10 arc-sec, 0.5 pixels, 30 m)

## Temporal

5 day revisit 600 km ( $\pm 25.5^\circ$  at 626 km altitude)

Orbit Crossing 10:30 am sun synchronous descending

## On-Orbit Calibration

Lunar View 1 per month {radiometric}

Blackbody Views 1 per scan {radiometric}

Deep Space Views 1 per scan {radiometric}

Surface Cal Experiments 2 (d/n) every 5 days {radiometric}

Spectral Surface Cal Experiments 1 per year

## Data Collection

Compression  $\geq 2.0$  lossless

# Mission Concept Status

- **Spacecraft Partner :** TBC
- **Instrument Partners:** JPL/GSFC
- **Launch Vehicle:** TBC: Taurus, Minotaur, Falcon 9
- **Launch date:** 2021 TBC, seeking partner for earlier launch opportunity
- **Mission Duration:** 3 years with 5 years of expendables
- **S/C & Instrument Mass:** 520 kg (31% margin)
- **S/C & Instrument Power:** 620W (64% margin)
- **Mission Cost:** \$506M include 30% reserve before launch

**Thank You**